OPTICALLY ENHANCED

ATTITUDE AND HEADING REFERENCE SYSTEM

OptoAHRS

Demo Program

User's Manual

Revision 1.3

Revision history

Revision	Date	Author	Description
1.0	17-Jan-14	IB	Released version
1.1	31-Jan-14	IB	Added instructions how to make the device output either true or magnetic heading and azimuth
1.2	26-Mar-14	IB	Added an Appendix describing the ".bin file data format
1.3	20-Aug-14	IB	Added loop closure flag information

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Introduction

The Inertial Labs™ OptoAHRS Demo program is designed to study and monitor operation of the of Inertial Labs™ OptoAHRS.

The operation of the Inertial Labs™ OptoAHRS is performed and controlled through calling the procedures and functions of the Inertial Labs™ OptoAHRS SDK (see Inertial Labs™ OptoAHRS SDK user's manual).

The source code of the OptoAHRS Demo program (developed with the C# programming language and provided by Inertial Labs™) may be used as a sample source code of how the above procedures and functions shall be called

Fig: 1.1. Inertial Labs™ OptoAHRS

1. System Requirements

Supported platforms: Windows XP, Windows Vista, and Windows 7

Hardware requirements:
- Pentium IV processor with a clock frequency of at least 1.5 GHz or higher
- USB 2.0 on board Interface

Software requirements:
- iCube Camera Device Driver
- iCube Cognex AIK Setup
- FTDi COM-to-USB converter driver

2. Software Installation

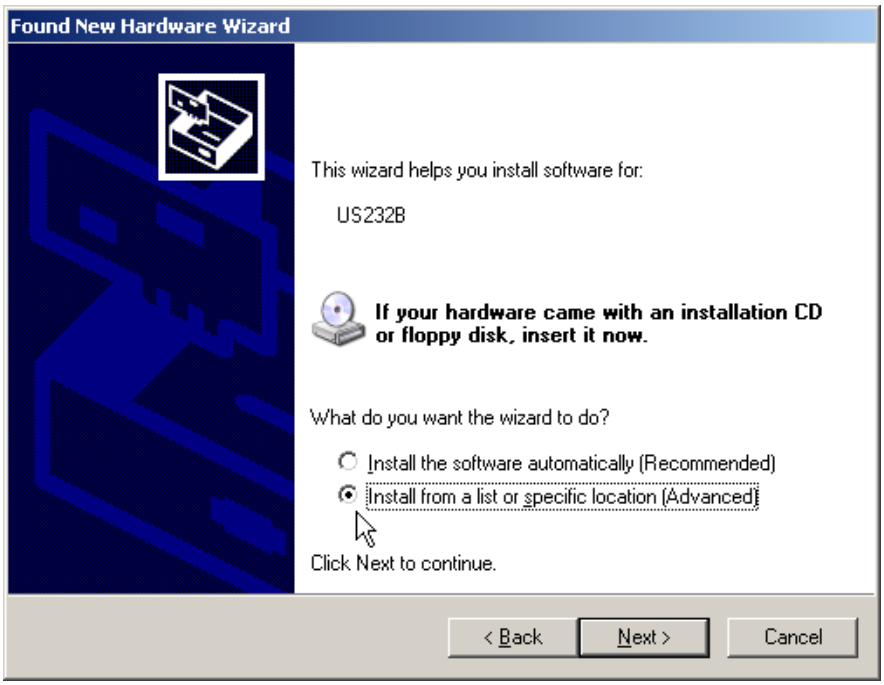
2.1. COM-to-USB Converter Driver

Administrator rights are necessary for installing a driver

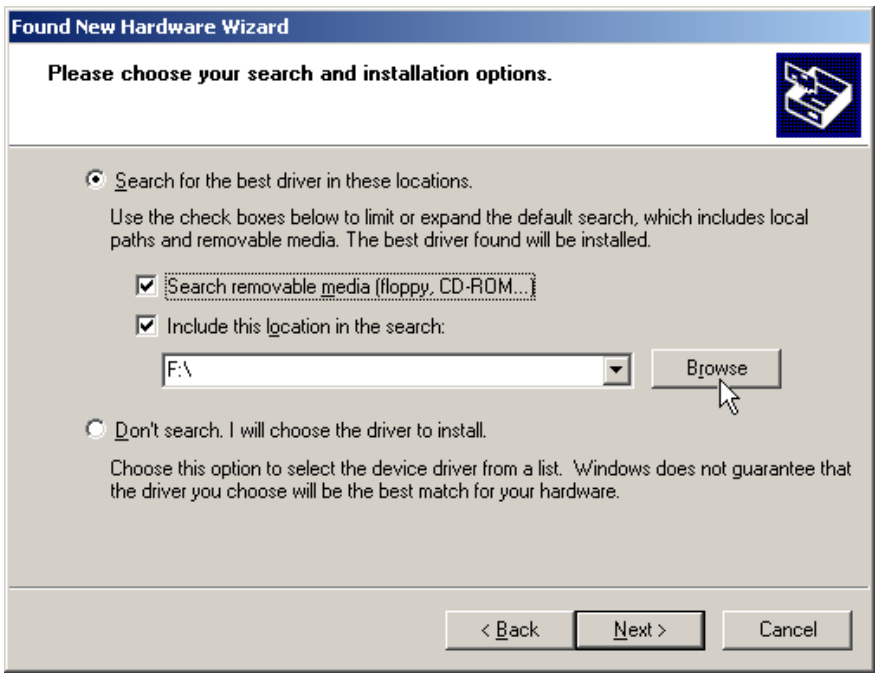
Connect the OptoAHRS to a PC. The following window will appear on the screen:

Found New Hardware Wizard
Welcome to the Found New Hardware Wizard
Windows will search for current and updated software by looking on your computer, on the hardware installation CD, or on the Windows Update Web site (with your permission).
Read our privacy policy
Can Windows connect to Windows Update to search for software?
Yes, this time only
Yes, now and every time I connect a device
No, not this time
Click Next to continue.
< Back
Next >
Cancel

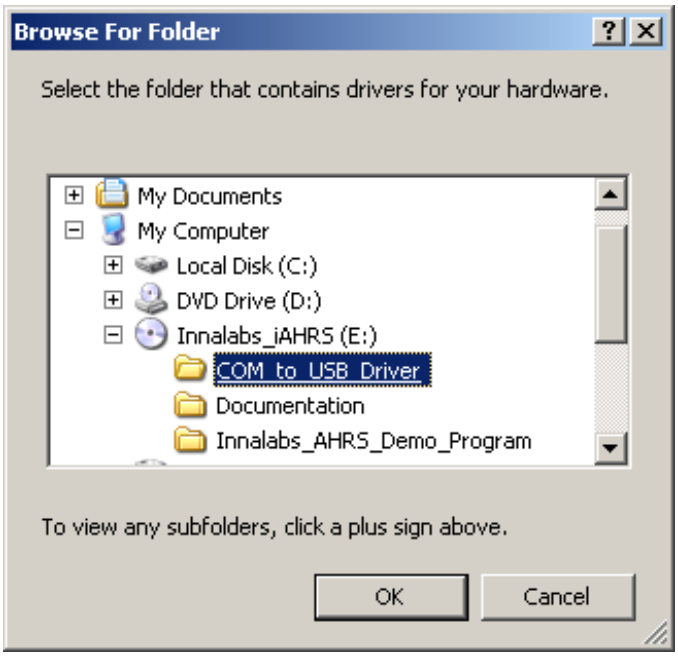
Select **No, not this time,** click **Next.** The following window will appear:


Found New Hardware Wizard
This wizard helps you install software for:
US232B
If your hardware came with an installation CD or floppy disk, insert it now.
What do you want the wizard to do?
Install the software automatically (Recommended)
Install from a list or specific location (Advanced)
Click Next to continue.
< Back
Next >
Cancel

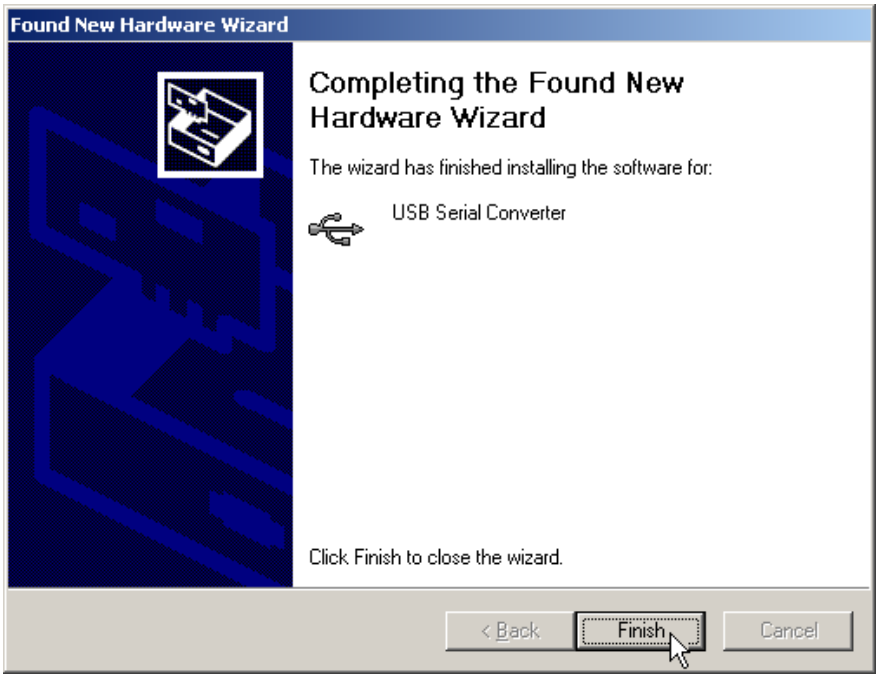
Select **Install from a list or specific location (Advanced)**, click **Next,** and have the following window on your screen:


Found New Hardware Wizard
Please choose your search and installation options.
Search for the best driver in these locations.
Use the check boxes below to limit or expand the default search, which includes local paths and removable media. The best driver found will be installed.
Search removable media (floppy, CD-ROM...)
Include this location in the search:
F:\
Browse
Don't search. I will choose the driver to install.
Choose this option to select the device driver from a list. Windows does not guarantee that the driver you choose will be the best match for your hardware.
< Back
Next >
Cancel

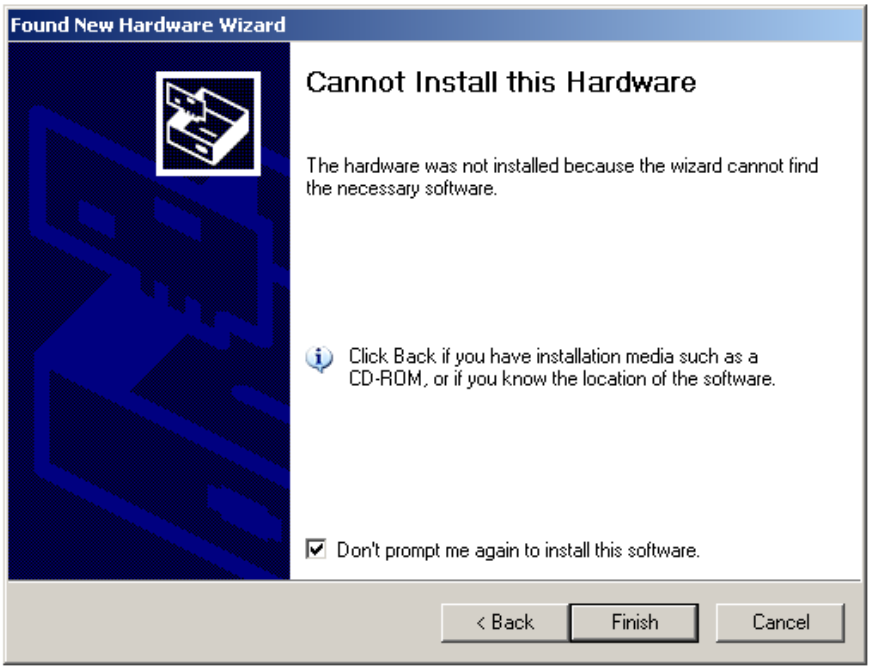
Check **Include this location in the search,** click **Browse,** show the path to the converter driver folder in the following window (folder name may differ from those in the figure), and click **OK** (if a folder containing no driver files is selected, **OK** will remain inactive).



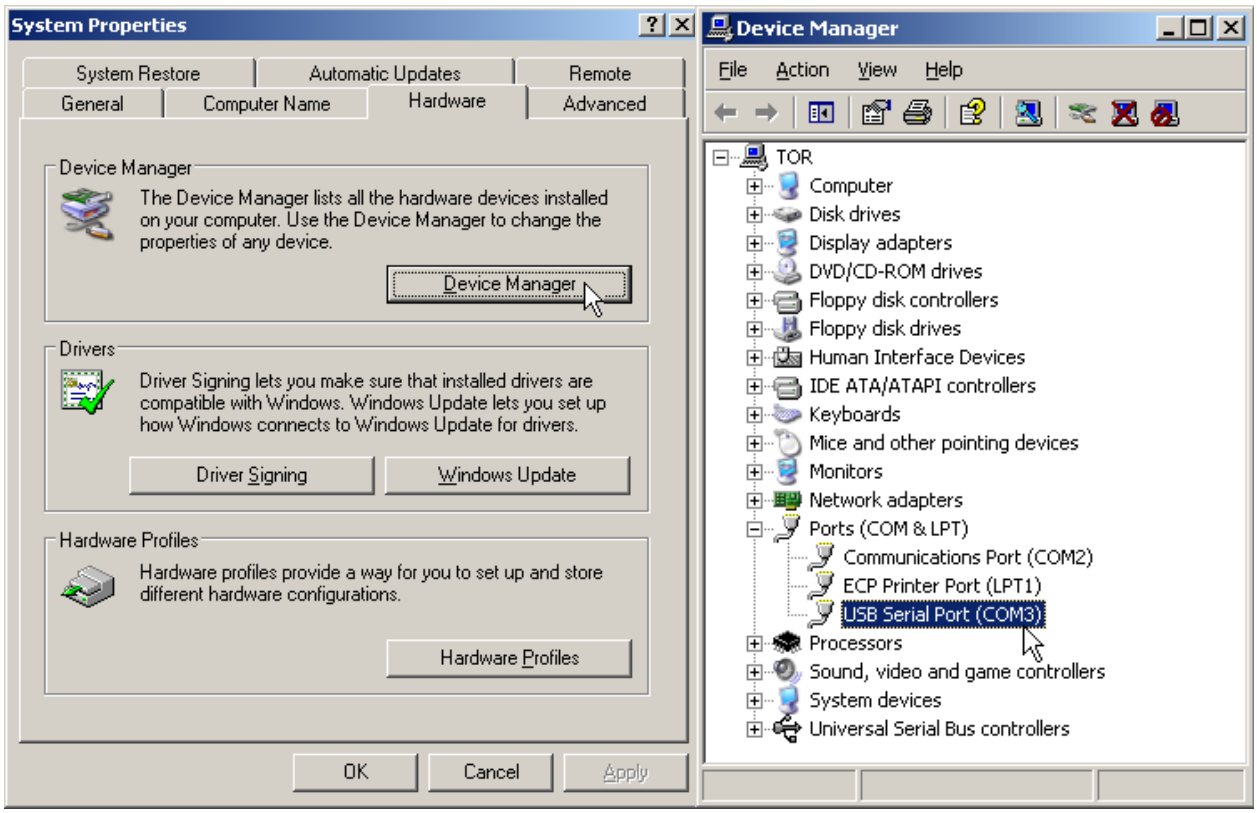
Then click **Next** in the previous window to to continue installation. The program will automatically start the installation. If installation is successful, the following window will appear:



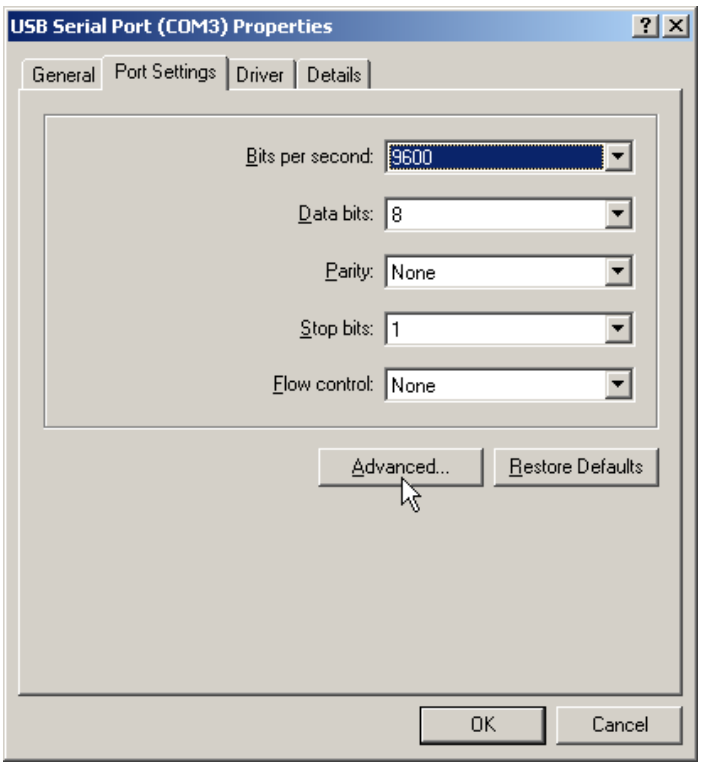
Press **Finish** to complete installation. If the rivers are not installed, an error message another window will appear (see below). In this case, click **Back** and set another path to the driver files.


Found New Hardware Wizard
Cannot Install this Hardware
The hardware was not installed because the wizard cannot find the necessary software.
Click Back if you have installation media such as a CD-ROM, or if you know the location of the software.
Don't prompt me again to install this software.
< Back
Finish
Cancel

Once the converter driver is installed, you will need to know the number of the additional COM-port set by the system and configure parameters of this port for correct operation of the OptoAHRS. To do so, click **Device Manager** in the **System Properties** window of your PC (**Hardware folder**) (see below). In the opened «Device Manager» window (see below) this COM-port will be marked as **USB serial port (COMN)**, where N in the port name will be assigned by your computer.



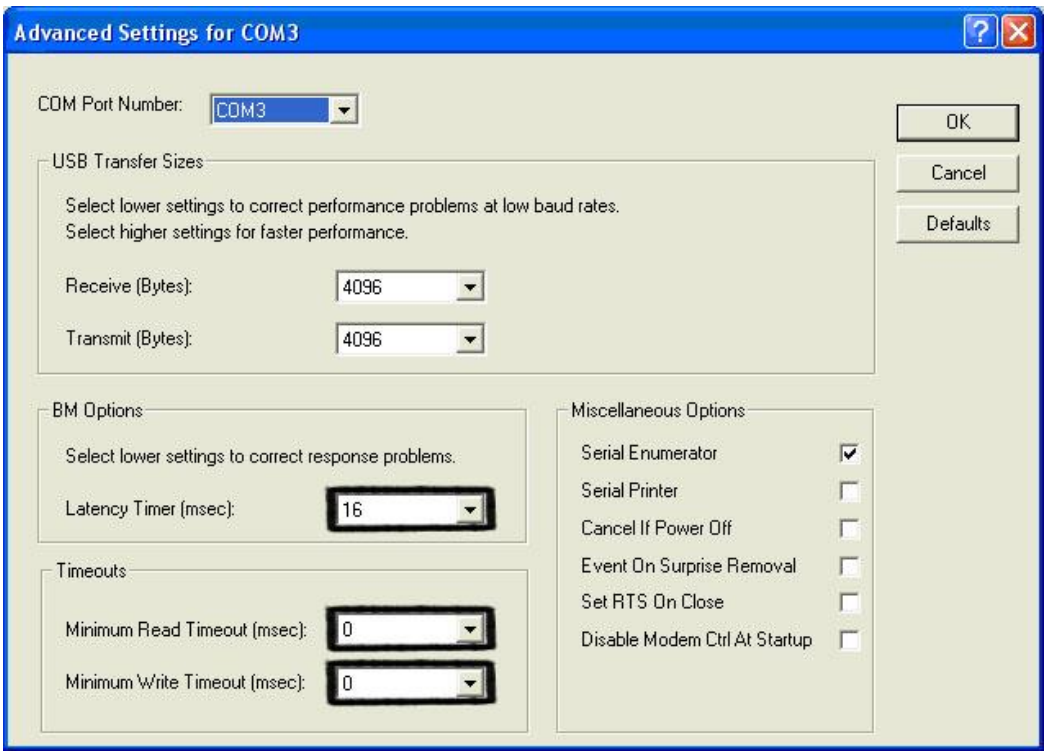
Then right-click on the port name, select **Properties,** and select the **Port Settings** folder, then click **Advanced** (see the figure below):



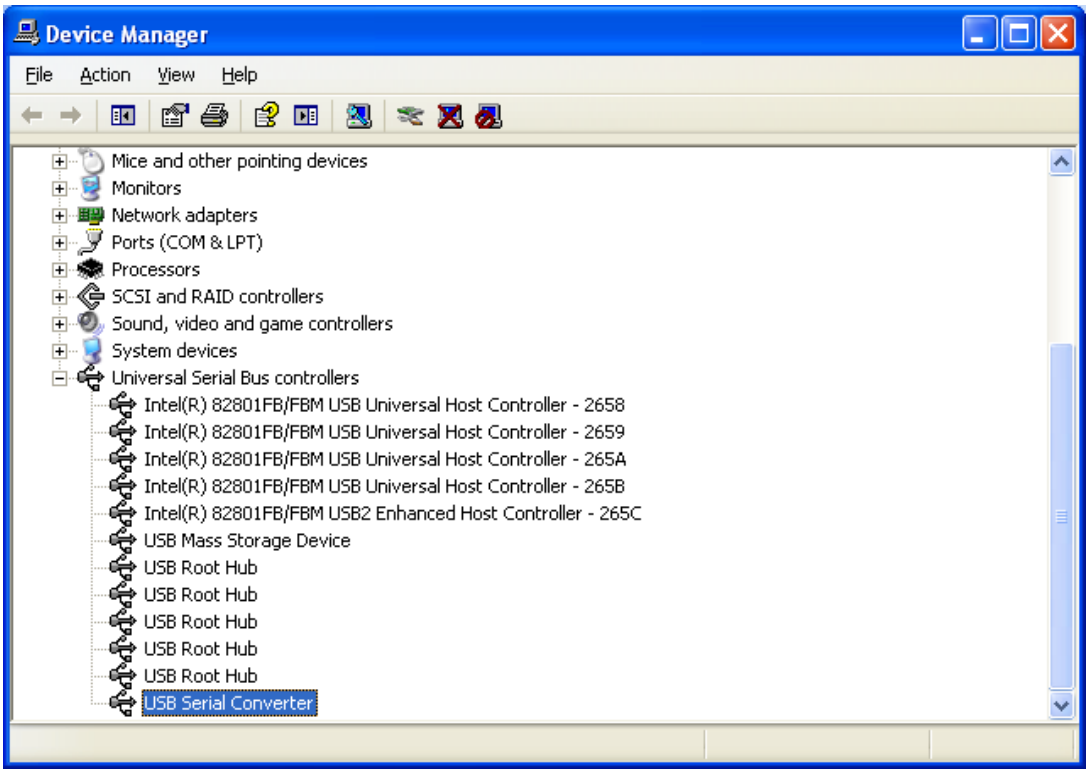
In the appeared **Advanced Settings** window set the parameters as follows:

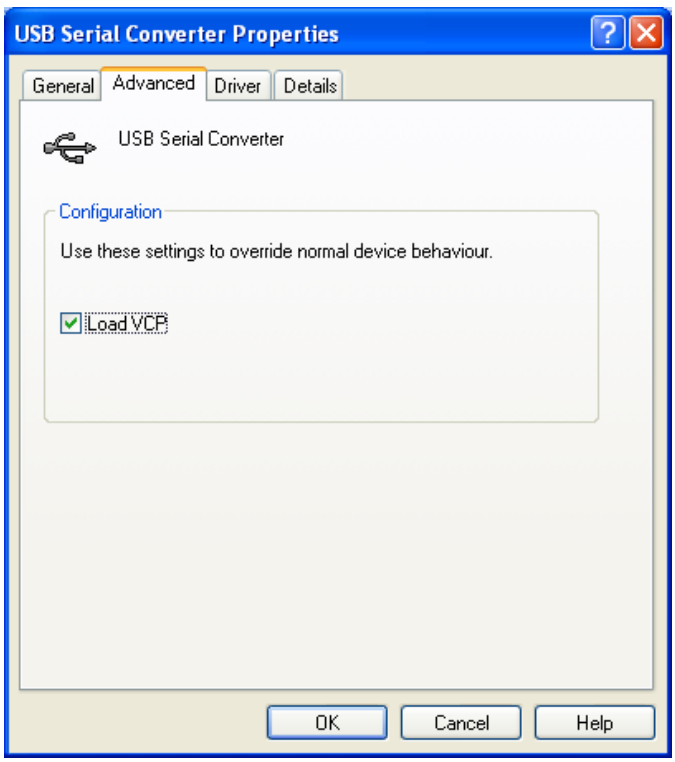
- Latency Timer (msec) to **16**
- Minimum Read Timeout (msec) to **0**
- Minimum Write Timeout (msec) to **0**

as it is shown in the next figure, and click **OK:**



In the case of some problems with the COM-to-USB driver operation, you will need to make one more adjustment to the driver properties. In the **Device Manager** window, go to the **Universal Serial Bus controllers** section (see the first figure below). Twice click **USB Serial Controller** to set its properties. The **USB Serial Controller Properties** window will appear. Click **Advanced** there and check the **Load VCP** box (see the second figure below).


Device Manager
File Action View Help
Mice and other pointing devices
Monitors
Network adapters
Ports (COM & LPT)
Processors
SCSI and RAID controllers
Sound, video and game controllers
System devices
Universal Serial Bus controllers
Intel(R) 82801FB/FBM USB Universal Host Controller - 2658
Intel(R) 82801FB/FBM USB Universal Host Controller - 2659
Intel(R) 82801FB/FBM USB Universal Host Controller - 265A
Intel(R) 82801FB/FBM USB Universal Host Controller - 265B
Intel(R) 82801FB/FBM USB2 Enhanced Host Controller - 265C
USB Mass Storage Device
USB Root Hub
USB Root Hub
USB Root Hub
USB Root Hub
USB Root Hub
USB Serial Converter


USB Serial Converter Properties
General Advanced Driver Details
USB Serial Converter
Configuration
Use these settings to override normal device behaviour.
Load VCP
OK Cancel Help

2.2. Camera Driver

Administrator rights are necessary for installing a driver

1. Copy the Camera Driver folder to your PC directory.

2. Plug the OptoAHRS USB connector into your USB 2.0 port.

3. Windows plug and play manager recognizes the new hardware.

4. Follow the instruction of the windows plug and play manager.

5. After the iCube driver was installed, you can see on the device Manager / imaging devices the recognized iCube camera (_ NET Icube_Cam Device):

2.3. OptoAHRS Demo Program

The Inertial Labs™ OptoAHRS Demo program does not require any installation. Just copy the program folder to your working directory.

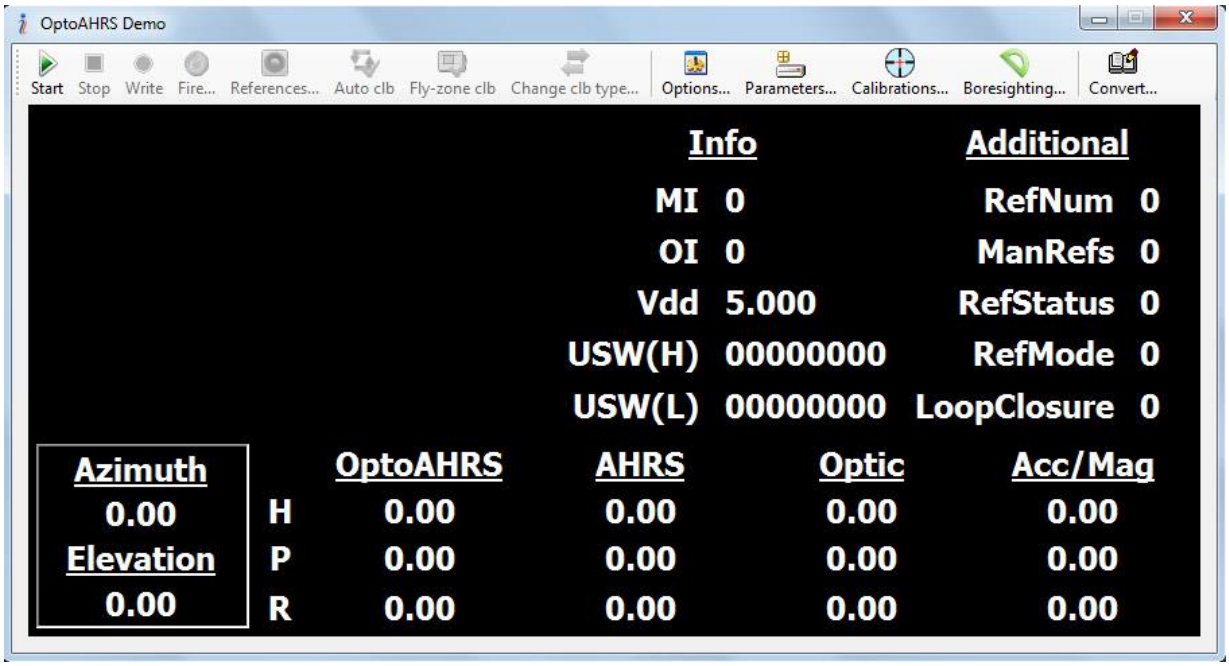
3. OptoAHRS Operation

3.1. Running the OptoAHRS

1. Connect the OptoAHRS to power and make sure that the red LED on the device's right side is on.

2. Plug the OptoAHRS USB connector into your USB 2.0 port and make sure that you have the appropriate COM-port number (see Section 2.1).

3. Run the OptoAHRS Demo program from its folder. You will see the following window on your screen:



4. Click **Options** to set the appropriate COM-port number (see Section 2.1) in the **Serial port number** window. Then click **OK.**

5. Click **Parameters** to set your current position latitude (in degrees), longitude (in degrees), altitude (in meters), and the current date. Then, in the case you want the device to output during operation (see Section 3.2)

EITHER

(a) ***True heading and azimuth*** *(heading and azimuth relative to the true north):* Either click **Auto** to have your current magnetic declination (calculated based on the WMM expressions) in the **Mag. declination**

window or, if you have a more accurate magnetic declination value for your place, enter it in the **Mag. declination** window from your keyboard;

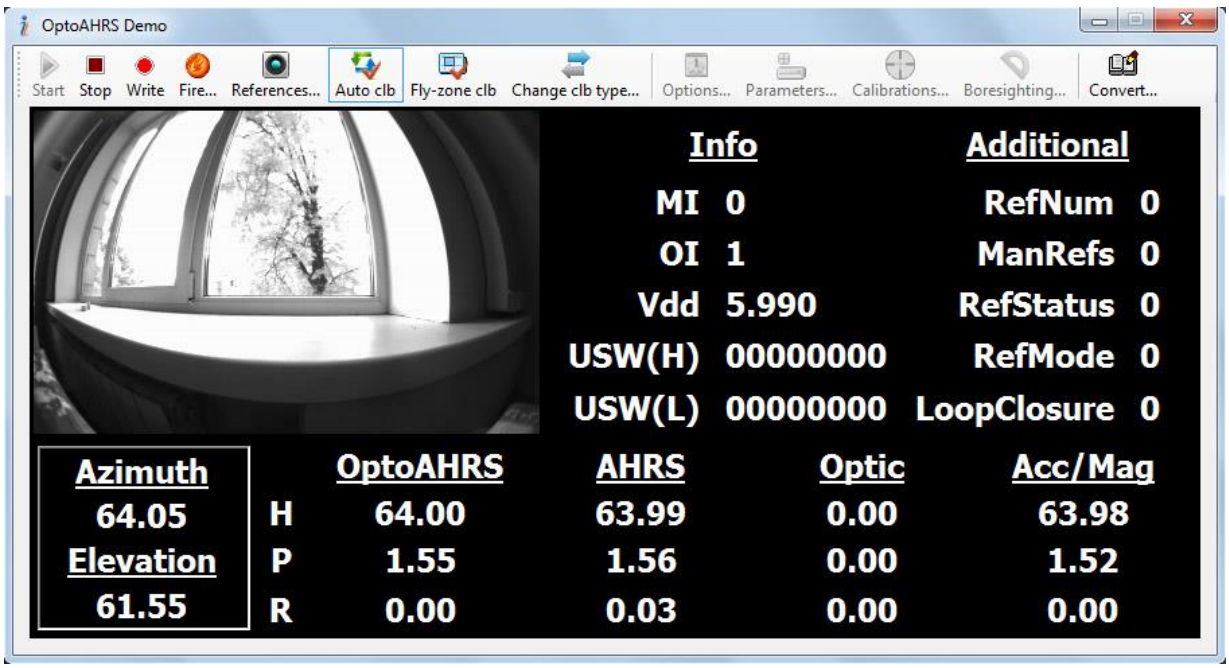
OR

(b) ***Magnetic heading and azimuth*** *(heading and azimuth relative to the magnetic north):* Enter "0" in the **Mag. declination** window from your keyboard.

Then click **OK** to save the parameters into the device memory.

Note: Even if you are not going to require the program to calculate your current magnetic declination (in the case you have your own magnetic declination value for your place or you need magnetic heading and azimuth – see above), you must set the correct latitude, longitude, altitude, and date, since they are needed for correct operation of the magnetometer auto-calibration algorithm (see Section 4.3).

6. Click **Start** to start the OptoAHRS. You will see the current camera view in left part of the program window. Wait for 10 sec (this time may be reduced or increased on Customer's request) for the device to complete its initial alignment. Upon the initial alignment, the device will start showing its current orientation output:



Important Note: *During the initial alignment, the device must be* ***completely unmovable!*** *Otherwise the initial alignment will be unsuccessful!*

Notes:
1) If, when you click **Start,** no camera image appears in the left part of the program window, please remove the camera lens cap from the device.
2) To start the optical part of the OptoAHRS, you must create, at least, one reference frame manually (see section 4).
3) To secure accurate tube's azimuth and elevation data, you must perform the bore-sighting procedure (see Section 5) before operation.
4) To secure the optimal accuracy of magnetometer data, you must perform one (or several) of the OptoAHRS hard and soft iron calibrations (3D, 2D, 2D/2T, or zone 3D) before operation (Section 6).

3.2. OptoAHRS Output Data

During OptoAHRS operation, the program shows the following device's output data in its window:

- ***Azimuth*** and ***Elevation:*** Tube's current azimuth and elevation angles
- ***H, P, R (OptoAHRS):*** Device's current heading, pitch, and roll calculated based on specially-fused optical, magnetometer, gyro, and accelerometer data with the use of Inertial Labs™ proprietary mathematics
- ***H, P, R (AHRS):*** Device's current heading, pitch, and roll calculated based on magnetometer, gyro, and accelerometer data (w/o optical orientation data)
- ***H, P, R (Optic):*** Device's current heading, pitch, and roll calculated based on optical orientation data alone
- ***H, P, R (Acc/Mag):*** Device's current heading, pitch, and roll calculated based on accelerometer and magnetometer data

When running, the program also shows some supplemental data related to OptoAHRS operation:

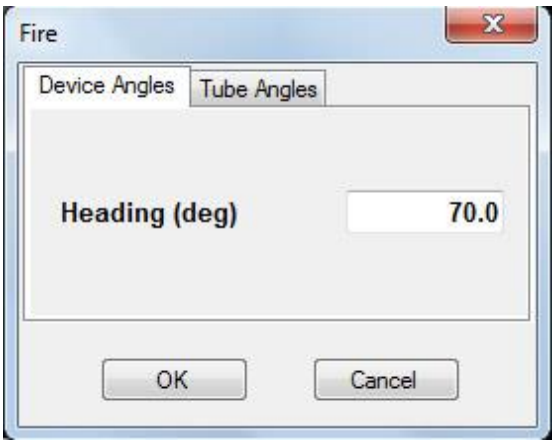
- ***MI:*** Magnetic interference (0 = no interference; 1 = there is some magnetic interference)
- ***OI:*** Optical interference (0 = no optical interference and good optical data; 1 = there is some optical interference, some obstacle, poor optical data, or no manually-created reference frames; 2 = optical interference becomes permanent, i.e. there is some optical obstruction)

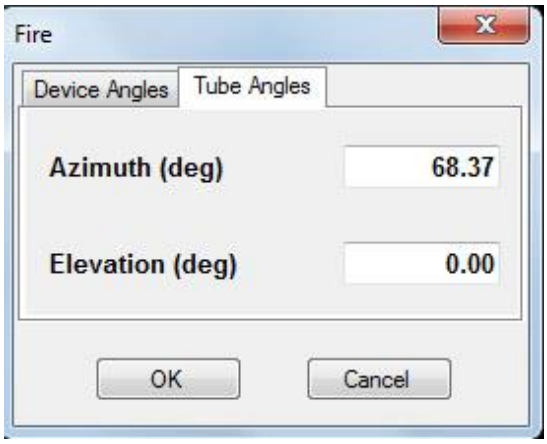
- ***Vdd:*** Power voltage (V) from the device internal power source
- ***USW(H/L):*** Device's status word (must be zero if everything is ok)
- ***RefNum:*** Total number of reference frames
- ***ManRef:*** Number of manually-created reference frames
- ***RefStatus:*** 0 = no manually-created reference frames; 1 = at least one reference frame has been created manually
- ***RefMode:*** Reserved
- ***LoopClosure:*** 0 = loop closure has not occurred yet; 1 = loop closure has already occurred in a run (see Section 4.2)

3.3. Menu Options Available during OptoAHRS Operation

During OptoAHRS operation, the following OptoAHRS Demo program menu options are available to the operator:

- ***Stop:*** Terminates OptoAHRS operation
- ***Write:*** Stops and starts writing OptoAHRS output data into a *.bin file in the ***data*** folder. The *.bin file may be converted into the text form with the use of the ***Convert*** menu option. Please see the Appendix for the *.bin file data format
- ***Fire:*** Allows saving device points with accurate heading and/or azimuth and elevation for further analysis of device's accuracy. When clicked, the following window will appear, where you can switch between the ***Device Angles*** and ***Tube Angles*** folders, depending of which of the angles (device's heading or tube's azimuth and elevation) you know accurately at a point:





Either you enter device's heading or tube's azimuth, the point will be saved (upon clicking **OK**) in two *.csv files (in the **data** folder) with device's output and accurate headings and tube's output and accurate azimuths (recalculated into each other). Later you may use this information to analyze OptoAHRS's accuracy.

- ***References:*** Allows creation of reference frames with either accurate device's headings or tube's azimuths manually (see Section 4)
- ***Auto clb:*** Turns on/off the magnetometer auto-calibration option based on optical data (see Section 4)
- ***Fly-zone clb:*** reserved
- ***Change clb type:*** Allows switching between different OptoAHRS hard and soft iron calibration parameter sets (Simple, Factory, 2D-2T/3D/2D, zone 3D, previous Auto-calibration) during operation
- ***Convert:*** Converts test OptoAHRS output data *.bin file into test form

4. Working with the OptoAHRS Optical Part

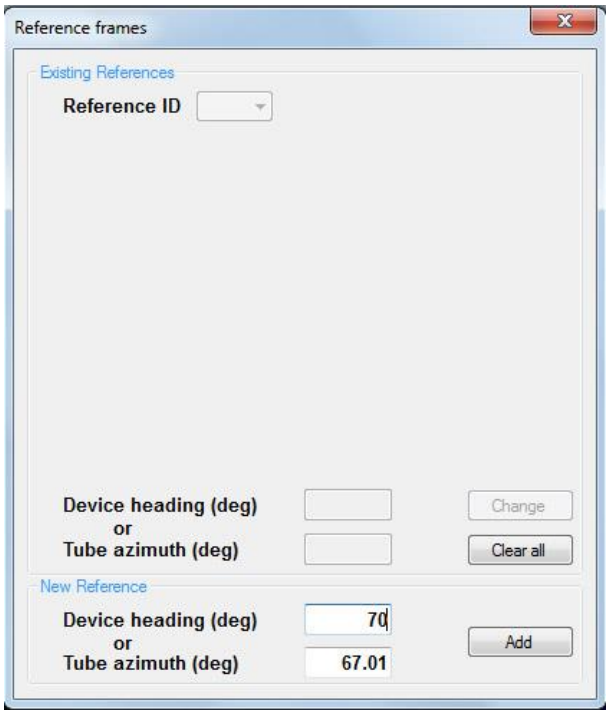
4.1. Running the Optical Part

The optical part of the device works through the use of **reference frames.** A reference frame is literally a picture of the camera view in a given direction. Within the reference frame the system identifies a constellation of identifiable features. Then, from any subsequent image collected by the camera, heading is determined by comparing those images back to the most appropriate reference.

To start the device optical part, you must manually create the first reference frame with a known heading. To do so, you must know accurate heading of your current position. You may obtain it in one of the following three ways:

- To measure OptoAHRS current heading with an external device (like a gyrocompass) put onto the top of the OptoAHRS
- To measure tube's current azimuth with some external means (to make it correctly work you must perform the bore-sighting procedure (see Section 5) before operation)
- To use device's current heading shown in the OptoAHRS column upon starting the OptoAHRS (see section 3.1) (to make it correctly work you must perform one of the OptoAHRS hard and soft iron calibrations (3D, 2D, 2D/2T, or zone 3D) before operation (see Section 6))

To create a new reference (including the first one), click **References.** In the ***New Reference*** section of the window that appear (see below), enter device's accurate heading or tube's azimuth (see above) and click **Add:**

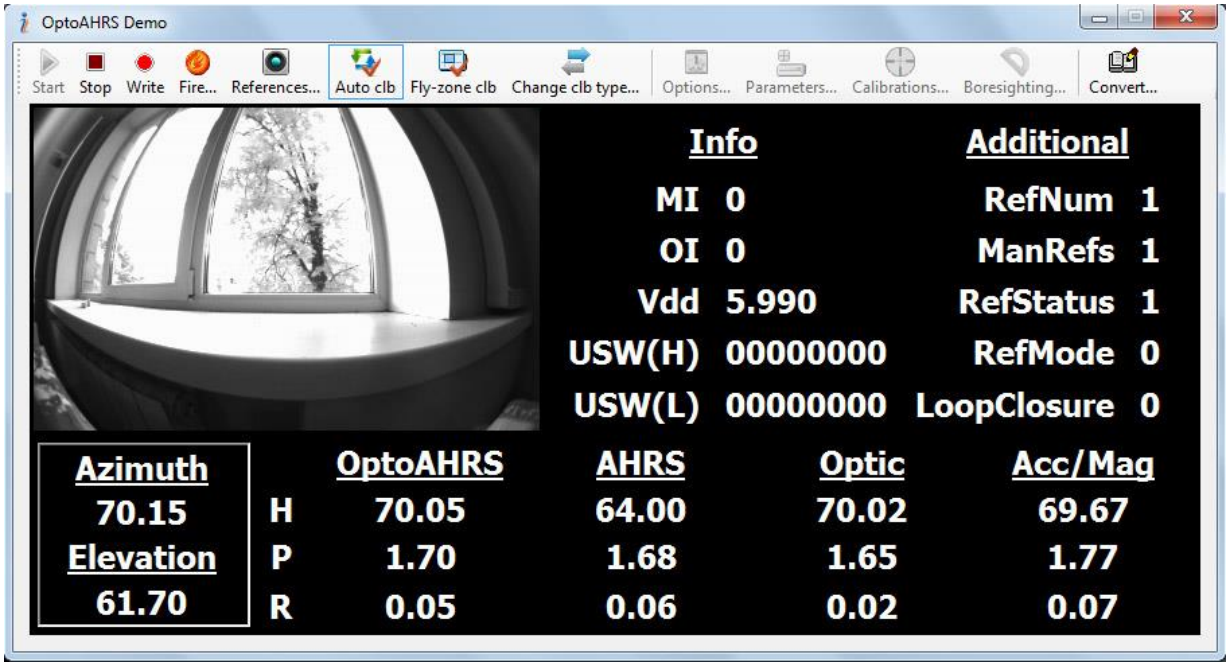


Upon clicking **Add,** the new reference frame image together with reference frame device heading and tube azimuth will appear in the upper part of the window:

If you have created the first reference frame, two more windows describing optical data input in the graphical form will appear on your screen.

Notes:
1) When creating a new reference, you may enter either device heading or tube azimuth. That of the two angles that is entered last before clicking **Add** will be used to create a new reference frame and will be recalculated into the other angle based on the bore-sighting results (see Section 5).
2) If you have entered incorrect device heading or tube azimuth when creating a reference, you may make correct them in the upper part of the ***Reference frames*** window later by selecting the reference frame number, entering the correct angle number in the corresponding window, and clicking **Change.**

Upon creating a reference frame, you may close the ***Reference frame*** window. In the main program window, ***RefNum*** and ***ManRef*** must increase by 1. If you have created the first reference frame, ***OI*** will change from 1 to 0, and the program will start showing its orientation output in the ***Optic*** column:



If, during OptioAHRS operation, you will have other points with accurate device headings or tube azimuths, you may add additional reference frames manually as described above.

Important Note: The reference frame map from the current operation is saved in the ***data*** folder upon stopping the OptoAHRS. When you start the OptoAHRS next time (see Section 3.1), the program will check if there is a reference frame map file in this folder and, if there is, it will ask if it shall load it for the current operation. You may click **yes** only if the device

has stayed at the same place and its surroundings have not changed. Otherwise, you shall click **no.**

4.2. Loop Closure

When, during OptoAHRS operation, the device camera makes a full 360 degree rotation around its vertical (heading) axis, the OptoAHRS image processing algorithm is able to catch this moment and to introduce appropriate corrections to the headings of all the reference frames created over the whole circle. This moment is called ***Loop Closure.*** Upon it, the accuracy of OptoAHRS heading improves 2-3 times and achieves the heading accuracy stated in its datasheet.

Because of the above, it highly recommended that, upon starting the OptoAHRS (see Section 3.1) and starting its optical part (see Section 4.1), you rotate the device together with its carrier around device's vertical (heading) axis over the whole circle at a rate of no more than 10 deg/sec to make a loop closure before operation.

4.3. Magnetometer Auto-calibration

The carrier which the device is mounted on usually creates magnetic fields that make magnetometer data unfit for calculating device's heading. That is why, any magnetic system needs calibration for hard and soft iron upon installation on its carrier (see Section 6). In the case of the OptoAHRS, valid magnetic data is needed to rely on for heading updates when optical data becomes unavailable for one reason or another (some obstacle to the camera view, poor lightness conditions, etc.).

The magnetometer auto-calibration algorithm allows you to calibrate the hard- and soft-iron parameters of the carrier which the device is mounted on automatically based on the current optical orientation data. In general you may start the OptoAHRS without any hard and soft iron calibration at all and within some time have the full set of magnetometer parameters, provided that valid optical data has been available during this operation. In reality the magnetometer auto-calibration eliminates the need to perform any of the hard and soft iron calibrations (section 6) before device operation.

Moreover, the auto-calibration algorithm is able to track any changes in the hard- and soft-iron parameter values that may occur during device's operation.

The auto-calibration may start from any of the calibration sets stored in the device memory (Factory, 2D-2T/3D/2D, zone 3D, previous Auto-calibration) or without any calibration all. However, whichever of the parameter sets it starts from, the general rule is following:

The magnetometer parameters resulted from the auto-calibration are valid only within a zone that is wider by some 15-20% the zone where the device has been working during the current run when valid optical data has been available (i.e. when OI = 0).

For example, you started the device and were working in a zone when device's heading varied from 20 to 80 degrees and pitch from -20 to +20 degrees, when valid optical data was available. If at some time, valid optical orientation becomes unavailable (***OI*** = *1*), you may continue working in the zone between 10 to 90 degrees in heading and between -25 to +25 degrees in pitch relying on magnetometer data with applied current auto-calibration results. If you are going to leave this zone, you shall switch to another set of parameters with the use of the ***Change clb type*** option.

To make the auto-calibration parameters valid within the whole OptoAHRS optical part operation range (0 to 360 degrees for heading; and ±22.5 degrees for pitch and roll), you shall make three circles around device vertical (heading) axis at pitches of about 0, -20, and +20 degrees, with valid optical data (***OI*** = *0*) available, upon starting the OptoAHRS (see Section 3.1) and starting its optical part (see Section 4.1).

The auto-calibration option may turn on and off at any time during operation by clicking ***Auto clb.***

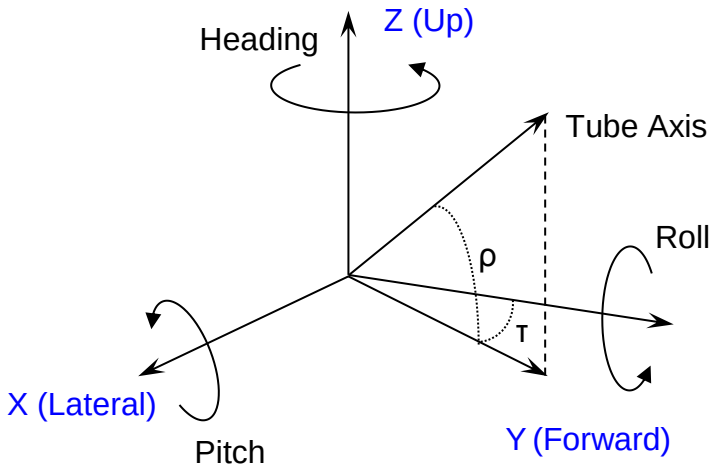
When you start the OptoAHRS, by default the auto-calibration will be ON when you starts with the Simple, Factory, and 2D-2T/3D/2D parameter sets, and OFF when you start with the zone 3D parameters.

You may change the magnetometer parameter set you start with by clicking **Parameters,** selecting the required parameter set in the ***Mag field calibration*** zone, and clicking **OK.**

5. Bore-sighting

Bore-sighting is required to enable the device to output accurate tube's azimuth and elevation. The purpose of the Inertial Labs™ bore-sighting

procedure is to estimate the following two angles that define the tube axis orientation relative to the OptoAHRS axes:



On the figure above, ρ and τ are the tube pitch and heading offsets, correspondingly.

The user may set the tube pitch and heading offsets with the use of the **Boresighting** menu option. Upon clicking **Boresighting**, the following window will appear:

In the two upper windows, you will see the heading and pitch offsets (in degrees) currently stored in the device memory. If you have other tube offset values estimated with your own procedure, you may enter them into the windows and click **Save.** The angles will be saved into the device memory.

You may also perform the Inertial Labs™ proprietary bore-sighting procedure to estimate the tube pitch and heading offsets:

1) Enter some approximate (to within ±10 degrees) tube heading and pitch offset values into the two upper windows and click **Save.**

2) Measure the tube actual elevation with some special means (in mils) and enter it into the lower window (or adjust the tube to this elevation) and click **Next.**

3) Upon completion of step 1, align the tube sight reticle to some aim and click **Next.**

4) Within about 10 sec (when the corresponding instruction appears in the window), turn the tube together with the device to align the device sight reticle to the same aim and click **Next.**

5) When the **Accept** button appears in the lower right part of the window, click it and you will see the bore-sighting results in the two corresponding windows above. Otherwise, if the program is unable to complete the procedure, it will ask you to find another place in a better optical environment to perform bore-sighting.

6. Magnetic Field Calibration

6.1. Calibration Procedures

The carrier which the device is mounted on usually creates magnetic fields that make magnetometer data unfit for calculating device's heading. That is why, any magnetic system needs calibration for hard and soft iron upon installation on its carrier (see Section 6). In the case of the OptoAHRS, valid magnetic data is needed to rely on for heading updates when optical data becomes unavailable for one reason or another (some obstacle to the camera view, poor lightness conditions, etc.).

Inertial Labs™ has developed several types of magnetometer calibrations for hard and soft iron for the OptoAHRS depending on the conditions it is going to be use under. They include:

Important note: Before any of the calibrations below, you shall set the correct coordinates **Latitude**, **Longitude**, **Altitude,** and **Date** in the **Parameters** menu.

2D calibration is designed for carrier objects that move with small pitch and roll angles (not more than a few degrees). The calibration procedure involves a few full 360° rotations in the horizon plane of the carrier object

with the installed OptoAHRS (see Fig. 1 below). During this calibration pitch and roll angles must be as close to zero as possible.

For **3D calibration** the carrier object is rotated in the horizon plane (the Z-axis is up) with periodical stops about each 90 degrees for tilting in pitch and roll (see Fig. 1 - Fig. 3 below). After full 360° rotation the object with the OptoAHRS is turned over (the Z-axis is down) and the procedure described above should be repeated. During this calibration the range of pitch and roll angles changing must be as much as possible.

2D-2T calibration is designed instead of 3D calibration for carriers that operate with limited range of pitch and roll angles. This calibration involves several (two or more) 2D calibration procedures but with different pitch angles. During every 2D calibration run with set pitch angle, roll angles must be constant as possible. In the calibration those OptoAHRS readings are used only in which pitch and roll differ from their median not more than some inclination threshold.

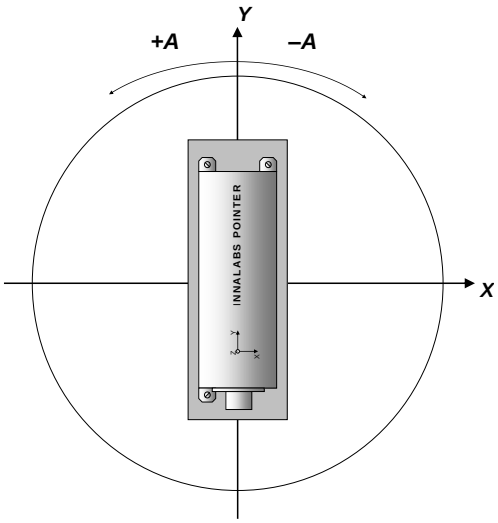


Fig. 1: Rotation of the carrier with OptoAHRS in horizontal plane

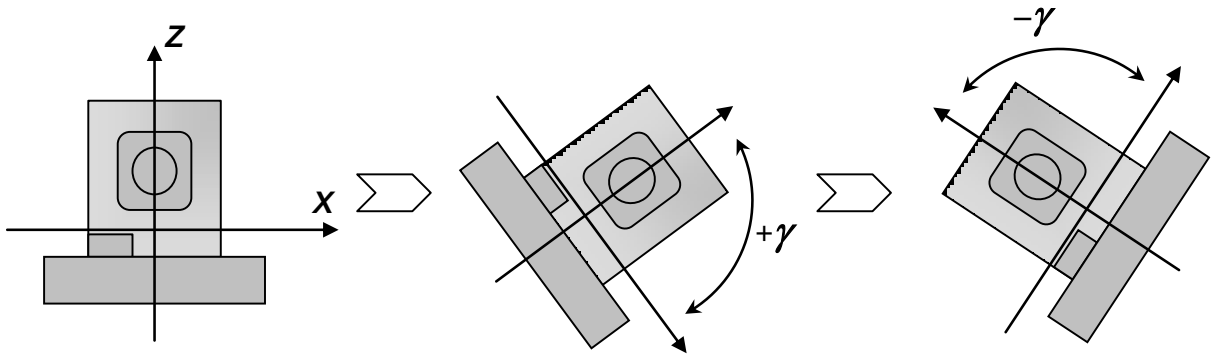


Fig. 2: Rotation of the carrier with OptoAHRS in roll

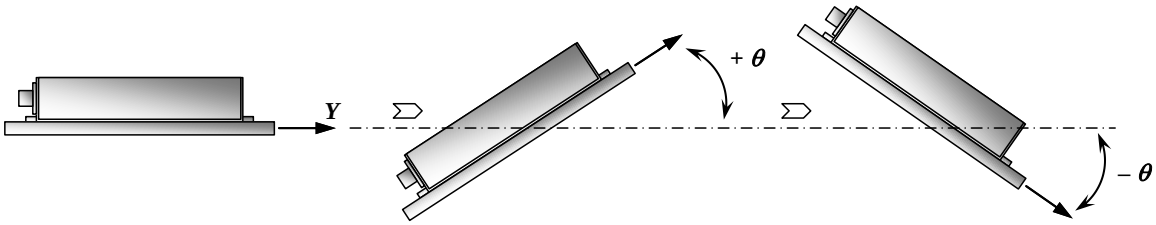


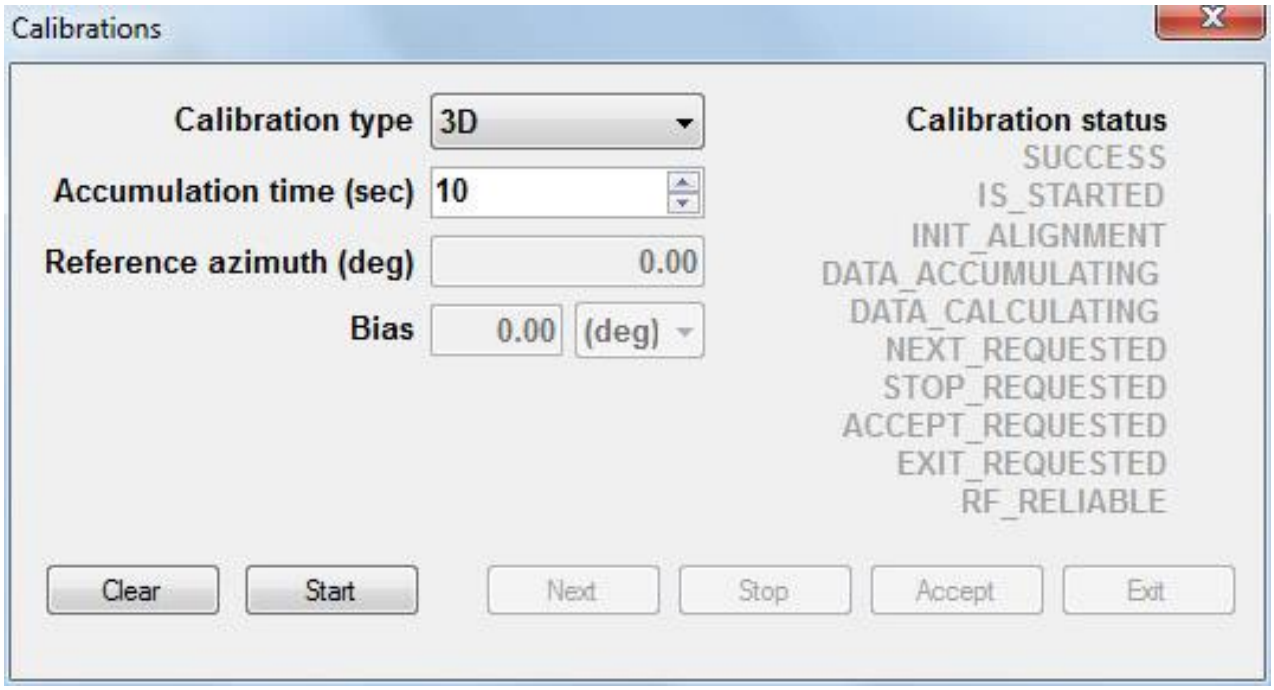
Fig. 3: Rotation of the carrier with OptoAHRS in pitch

Be aware that rotation of the carrier object with the OptoAHRS onboard for all the above calibration procedures must include one or more full 360° turns in the horizon plane.

In contrast to the above calibrations within the full heading range, **3D zone** calibration does not require rotation of the carrier, but it involves pointing of the carrier with installed OptoAHRS to four corners (and intermediate points) of its operating zone. This zone is limited by the min/max azimuth and min/max elevation points based on the given tube type. Accurate device headings in these points should be known. Usually the heading of one (reference or center) point is known, and relative headings of the other points may be measured by some tube sight unit or similar device (like a theodolite).

6.2. Performing the Calibrations

To start any of the above calibration procedures, please click **Calibrations** in the main program menu. The following window will appear:



1) Select the calibration procedure you are going to perform in the ***Calibration Type*** window.

2) In the ***Accumulation time*** window, set the time (in seconds) you will require to perform all the above rotations for the **2D** and **3D** calibration procedures, one or two rotations at one pitch angle for the **2D-2T** calibration procedure, and 10 sec for the **zone 3D** calibration. Then click **Start.**

In the case of 3D or 2D calibration:

3) Wait for initial alignment to complete and, when the line **DATA_ACCUMULATING** turns from grey to brown, perform all the rotations described above for the selected procedure within the time set above and click **Accept.**

In the case of 2D-2T calibration:

3) Click **Next,** wait for initial alignment to complete and, when the line **DATA_ACCUMULATING** turns from grey to brown, perform one or several full 360-degree rotations around the device heading axis at a given pitch within the time set above. Then click **Next** and do the above at another pitch. Do the above for the rest of the pitch angles. Then click **Accept.**

Note: The **Accept** button will not become active, if, during the accumulation time, there was no rotation at all or the rotation you performed was too small. In this case please perform the calibration procedure one more time.

In the case of zone 3D calibration:

3) Enter the zone center point heading into the ***Reference*** **azimuth** window and click **Start.** Set the device to the first calibration point and enter its heading shift relative to the zone center point heading into the ***Bias*** window. Click **Next** and wait until data accumulation is completed and **Next** becomes active again. Then do the same for another point. Do the above for at least four points with different headings and pitches (the four corners of the zone are the best points for such calibration). Then click **Accept.**

Note: During the **zone 3D** calibration, in addition to magnetometer calibration, the program creates reference frames with accurate headings (in the ***data*** folder) that may be used later during OptoAHRS operation in this zone. To do so, you shall answer **yes** to the program question if it shall load old reference frames when starting the OptoAHRS next time.

Important Notes:
1) In all the calibrations above, the device must be ***completely unmovable*** *during the initial alignment! Otherwise data accumulation will not start and all the buttons except* ***Exit*** *become inactive! In such a case click* ***Exit*** *and then click* ***Start*** *to start the calibration again.*
2) In all the calibrations above, when you are rotating the device to perform the rotations required for a calibration, you shall not exceed the ***gyro angular rate range*** *(±300 deg/sec). Otherwise all the buttons except* ***Exit*** *become inactive during data accumulation! In such a case click* ***Exit*** *and then click* ***Start*** *to start the calibration again.*

Notes:
1) During any of the calibrations, you may follows its progress and see what you shall do by watching the signs in the right part of the window turning from grey to brown and back:
SUCCESS: the calibration is successful
IS_STARTED: the calibration is started
INIT_ALIGNMENT: initial alignment is in progress
DATA_ACCUMULATING: data accumulation is in progress
DATA_CALCULATING: data processing is in progress

NEXT_REQUESTED: click **Next** to start a calibration run
STOP_REQUESTED: you can click **Stop** to stop the current calibration run
ACCEPT_REQUESTED: you may click **Accept** to save calibration results into the device memory
EXIT_REQUESTED: you may click **Exit** to exit the calibration procedure
RF_RELIABLE: the reference frame created at a point of zone 3D calibration is valid
2) You may delete all the calibration results and clear the device memory from them by clicking **Clear.**

6.3. Conditions to Make a Calibration Successful

Success of the OptoAHRS calibration for carrier soft and hard iron essentially depends on magnetic environment at the place where this calibration is performed.

The best results will be obtained if a calibration is performed in a homogeneous magnetic environment where the magnetic force lines are parallel to each other. In this case only the influence of the carrier object on the OptoAHRS magnetometers takes place, and this influence can be compensated upon the calibration.

However, in reality the magnetic environment at places where calibration of the OptoAHRS is performed often is not homogeneous. This may lead to degradation of the calibration results since OptoAHRS magnetometers are disturbed both by iron of the carrier object and by curved outward magnetic field. In this case it may be very difficult to separate influence of these two disturbance sources.

Inertial Labs™ engineers have develop a special calibration procedure for separation of these sources of magnetic disturbance to take into account and compensate just influence of the magnetic field of the carrier object. But residual influence of non-uniformity of environmental magnetic field may still decrease the calibration accuracy. After a lot of experiments Inertial Labs™ engineers have determined acceptable limits of non-uniformity of environmental magnetic field at which the OptoAHRS heading accuracy after calibration is satisfactory.

If the OptoAHRS calibration procedure is performed in the strict accordance with the procedures described above, but is unsuccessful, then the place of calibration has large distortion of the Earth uniform

magnetic field. To fix this, please change the place of calibration. For example, usually bad places for calibration are office rooms, laboratories with large quantity of computers and other electronics equipment, roads with underground communications or pipelines, places near electric mains, etc.

But even in bad magnetic environment the calibration can be successful if the OptoAHRS rotates around its magnetometers (around the point about 15 mm away from the OptoAHRS forward end). In this case the influence of non-uniformity of environmental magnetic field is minimal.

Finally, please remember that if the OptoAHRS carrier or the place of the OptoAHRS within the carrier is changed, a new calibration should be performed. If the OptoAHRS is going to be used alone without mounting on any carrier then any old calibration results should be cleared by clicking on **Clear** in the program ***Calibration*** window.

Appendix: OptoAHRS Saved Test Data *.bin File Format

If ***Write*** is clicked during OptoAHRS Operation (see Section 3.3), the program will create two binary files under the same name but with different extensions (*.prm and *.bin) in the ***data*** folder. The *.prm file contains the OptoAHRS parameters, while the *.bin file contains OptoAHRS output data. The format of the *.bin file is given below in this Appendix. The *.bin file may be converted into the text form with the use of the ***Convert*** menu option.

Table 1: First 50 Bytes of the *.bin File (Initial Alignment Data Package)

Byte	*Parameter*	*Format*	*Length*	*Note*
0-11	Gyros bias	float	3*4	3 numbers in ADC codes
12-23	Average acceleration	float	3*4	3 numbers in ADC codes
24-35	Average magn. field	float	3*4	3 numbers in ADC codes
36-39	Initial Heading	float	4	degrees
40-43	Initial Roll	float	4	degrees
44-47	Initial Pitch	float	4	degrees
48-49	USW	word	2	0 for successful initial alignment; ≠ 0 for unsuccessful one

Table 2: Structure of the Data Package Sent in Each Data Sampling Step (every 10 msec)

Byte number	0 – 1	2 – 3	4 – 5	6 – 7	8 – 9	10 – 11
Parameter	OptoAHRS Heading	OptoAHRS Pitch	OptoAHRS Roll	AHRS Heading	AHRS Pitch	AHRS Roll
Length	2 byte word	2 byte sword	2 byte sword	2 byte word	2 byte sword	2 byte sword
Note	Orientation angles (deg*100)			Orientation angles (deg*100)		

Byte number	12 – 13	14 – 15	16 – 17	18	19	20 – 21	22-23	24-25
Parameter	Optical Heading	Optical Pitch	Optical Roll	Optic Presence	Optic Type	Flag	Optic Features	Optic Matches
Length	2 byte word	2 byte sword	2 byte sword	1 byte	1 byte	2 byte sword	2 byte word	2 byte word
Note	Orientation angles (deg*100)				Idle		Idle	Idle

Byte number	26	27	28 – 31	32-35	36-39	40-43	44-47	48-51
Parameter	AutoClb	Reser-ved	Reser-ved	Mag Heading	Wdr X	Wdr Y	Wdr z	Azimuth
Length	1 byte	1 byte	4 byte	4 byte float	4 byte float	4 byte float	4 byte float	4 byte float
Note								

Byte number	52-55	56-59	60 – 63	64-67	68-71	72-75	76-79	80-81
Parameter	Elevation	Reser-ved	Reser-ved	Target Heading	Target Pitch	RefIDMod	HRefMod	FlyZone ClbPoint
Length	4 byte float	4 byte	4 byte	4 byte float	4 byte float	4 byte int	4 byte float	2 byte word
Note								

Byte number	82-83	84-85	86-87	88-89	90-99	100-135	136-171
Parameter	PLS Logical X	PLS Logical Y	PLS Diff X	PLS Diff Y	Reserved	Optic RefMean	Optic RefCov
Length	2 byte word	2 byte word	2 byte word	2 byte word	10 bytes	3*3*4 byte float	3*3*4 byte float
Note	Idle	Idle	Idle	Idle			

Byte number	82-83	84-85	86-87	88-89	90-99	100-135	136-171
Parameter	PLS Logical X	PLS Logical Y	PLS Diff X	PLS Diff Y	Reserved	Optic RefMean	Optic RefCov
Length	2 byte word	2 byte word	2 byte word	2 byte word	10 bytes	3*3*4 byte float	3*3*4 byte float
Note	Idle	Idle	Idle	Idle			

Byte number	172-189	190 – 191	192	193	194– 195	196 – 197	198 – 199
Parameter	Ugyro, Uacc, Umag	Shock	Shot	Reserved	USW	Vdd	Utermo
Length	9×2 byte sword	2 byte sword	1 byte	1 byte	2 byte word	2 byte word	2 byte sword
Note	Raw sensor data (gyros, accelero-meters, magne-tometers)	External shock sensor is required	Detected shot			Combined voltage VDC* 1000	Tempera-ture of each sensor